A Vibert Douglas "The Mystery of Motion" Publication

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The Mystery of Motion.

By A. Vibert Douglas, Ph.D.

Macdonald Physics Laboratory, McGill University, Montreal.

After discussing the various kinds of motion observed in the universe, the author asks whether astronomers have reached the climax in their survey of the motion of heavenly bodies. Interesting possibilities arise.

"NEVERTHELESS it moves"—Galileo, the aged thinker, bowed down in body and weary in spirit before his inquisitors, may not have spoken these words of stubborn defiance, but there is no doubt whatever that they represent the secret thought of that mighty intellect, in spite of the outward recantation forced from his lips in that tragic hour. Gone was the static earth of early eastern thought, gone was the geocentricism of the Chaldeans and of the majority of the Greek thinkers. Aristarchus of Samos had speculated more wisely than he knew, and the cautious Copernicus had set forth with compelling logic the theory of a rotating and revolving planet.

Still Unsolved.

The mystery of motion! This substantial earth, this *terra firma* beneath our feet, is not the motionless centre of the universe, but is a spinning, wobbling, curving, swerving, ever moving speck of stellar substance tracing out some exquisitely intricate path in the immensities of space. Three centuries have rolled by and still there are wise men striving to unfold the mystery of the true motion of the earth. Much has been learned but, like the evening mist in the Tyrolean mountains which dissolves away as you approach only to close in again with elusive, rosy fingers beckoning you towards the next defile, so this mystery of motion leads the astronomer on and on towards the hope of full understanding only to baffle him again with vague suggestions of motions on a still vaster scale—motions and yet other motions superimposed on the motions of which he has certain knowledge.

Spin and Wobble

Let us try to visualize the path in space followed by a point on the earth's surface. You, reader, may be the point, and perhaps you are situated near Lat. 51° N., Long. 0°. If the earth had no motion except its spin, the diurnal rotation on its axis which gives the succession of night and day, then you would describe a succession of perfect, coincident circles. Wearying of this monotony, you might wander about a little, walk along the street, cycle about a quiet countryside, motor to a neighbouring town and back—then your path or locus would no longer be a perfect circle but would show minute irregularities, small deviations from the smooth line, loops, cusps, curves, and microscopic zigzags. If, venturing further afield, you travelled towards the equator, your locus would become an expanding spiral. If you approached the poles, the spiral would grow smaller and smaller until at either pole your locus would shrink to a point.

But conditions are not so simple. The axis of the earth is not fixed in direction, but is wobbling like that of a slowly spinning top. Thus, instead of a succession of perfectly coincident circles we have each successive one tilted slightly relative to the previous one, and thus we picture a distorted closed spiral, bent, flattened, warped. This wobble is known as Precession, and is caused by the gravitational pull of the moon and the sun on the earth's equatorial protuberance. One complete wobble takes place in about 25,800 years, so that this effect upon the locus is barely perceptible from day to day, yet cumulatively it is very great. A further complication is introduced by the fact that this wobble is itself uneven, being now greater, now lesser according to the relative positions of moon and sun with reference to the plane of the earth's equator. The sinuosity thus imposed upon the precessional wobble is known as Nutation.

Thus, due to spin and wobble alone, a dweller at the equator is being carried through space at a speed of about 29 miles per second, while he who lives in Lat. 51° is borne around his spiral path at about 18 miles per second.

Orbital Motion.

As John Kepler discovered in the seventeenth century, the earth's orbit about the sun is an ellipse. In a little more than 365 days the earth makes its complete journey of something like 580 million miles around this orbit. Apart altogether, then, from spin and wobble, every point on the earth is being rushed through space around and around the sun at the rate of about 19 miles per second. The speed is greatest when the earth is in the part of its orbit nearest the sun, and decreases somewhat when at apogee or

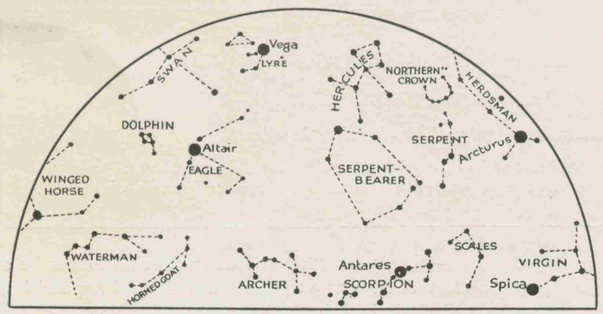

FIG. 1.
THE HEAVENS FROM LATITUDE 50° N.
Brightest stars in region of greatest star density, where the centre of our galaxy is believed to lie.

greatest distance from the sun. Endeavour now to combine these motions: the daily rotation, the long period wobble, and the yearly revolution. Truly it is a fantastic and beautiful locus that is being traced out by each of us as the hour-glass measures the passage of time.

Solar Motion

It was the inspired researches of that rare genius Sir William Herschel that first gave mankind the vision of a yet vaster motion which we were undergoing together with the sun, the moon, and all the planets and satellites of the Solar System. Close observation of the stars had revealed the fact that they are not "fixed" but freely moving bodies, and that it was quite possible to measure the changes in their relative positions from year to year, from decade to decade. The motions of many thousands of stars are now known with considerable accuracy, but in Herschel's day there were only seven stars whose motions were accurately measured. Yet with a boldness and a daring typical of his genius, Herschel set out to deduce from these seven observations the motion of the sun through space. Since he knew no reason why the stars should be moving in any particular direction he assumed that the mean velocity of any random group of stars, taking account both of the magnitude and of the direction of the motion of each, would be zero; and that if it were not zero then the resultant mean velocity was really an apparent effect due to the motion of the Solar System in the reverse direction. In this way he arrived at the conclusion that the sun is moving with a velocity of about 12 miles per second towards a point which lies in the constellation of Hercules between the bright, well-known stars Arcturus and Vega. This point towards which the entire Solar System is drifting is referred to as the Apex of the Sun's Way. All subsequent analysis of the vast accumulation of recent data as to the motions of the stars and star clusters, has confirmed in a very striking way this earliest determination of Herschel's, locating the Apex in the same region of the sky and finding the velocity of the sun to be of the same order of magnitude—approximately 12 miles per second.

Stellar Motions

Small but none the less important differences in the various determinations of Solar Motion and Apex, as determined from specially selected groups of stars (as, for example, the B stars, very bluish and mostly very distant; the Orion stars; the stars of the Pleiades group; the Ursa Major stars; the globular clusters), have proved that the assumption of random motion requires some modification. Just as each planet and satellite has its own peculiar motion as an individual, but partakes of the general motion of the solar system as a whole, so each star may have its random peculiar motion and yet certain groups of stars may have a group motion as well. Thus there are recognized clusters of stars, the members of which have a common space velocity; and when many stars scattered throughout many parts of the sky are found to have a kindred motion, this is referred to as "star streaming."

Two major star streams are well recognized, and various theories have been proposed in an effort to explain their motions. Is this vast assemblage of ten thousand million stars to be compared to two intermingling swarms of bees? Or is it really just one swarm, of ellipsoidal as opposed to spherical shape? All the stars of this assemblage, or let us call it the galaxy, are inevitably subjected to the gravitational attraction exerted from the mass-centre of the galaxy. Where is this centre? Are the stars perhaps revolving about it in elliptic orbits? As one cosmologist, Dr. L. Silberstein, has suggested, perhaps the galaxy is unstable and many of the stars, following hyperbolic orbits, will recede farther and farther from the centre of the galaxy and eventually escape entirely, passing out into intergalactic space.

Centre of Galaxy

One question which has very naturally arisen in the minds of astronomers is this—If we could view this galaxy from far out beyond the limits of the Milky Way, what would it look like? Would it perhaps look like a spiral nebula? Modern astronomy has discovered many thousands of these nebulae and found them to be each a galaxy of many million stars. In each of these there appears to be a central mucleus where the stars are less isolated from one another, and outside this the stars are grouped along

great outward sweeping arms and the main or preponderating movement of the individual stars is outward along the arms. If, instead of viewing one of these vast spirals from without, you viewed it from the vantage point of some star fairly near the nucleus, how would it appear? Would it present the appearance with which we are familiar in our own galaxy as seen from near the sun—a strongly marked, though somewhat irregular, galactic concentration or Milky Way, globular clusters, open clusters, star clouds, and the phenomena of star streaming? It is quite plausible, indeed it is almost certain, that these are just the characteristics that would be observed, and therefore it is at least a justifiable guess that the great aggregation of stars in which our sun has his place is in reality a spiral nebula. Assuming tentatively that this is the case, the astronomer seeks to interpret the known facts of the distribution and movements of the stars in the light of this hypothesis. First then let him discover, if he can, where is the nucleus, the centre of the galaxy.

Several regions of the sky have been proposed in this connexion, but the most favoured position has been in that richly star strewn portion of the Milky Way which lies in the constellation of Sagittarius. Quite recently at Harvard Observatory a systematic search for the region of greatest star density has confirmed the belief that the centre of the galaxy lies in the direction of the great star clouds in Sagittarius.

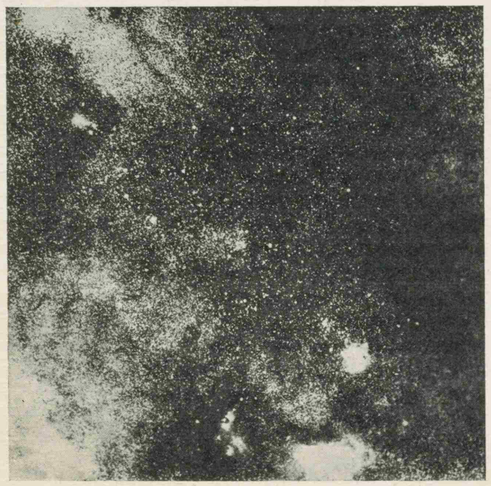

FIG. 2.
SAGITTARIUS.
Photograph of a region in Sagittarius north of the Great Star Cloud, from a 4 hour exposure by Barnard.

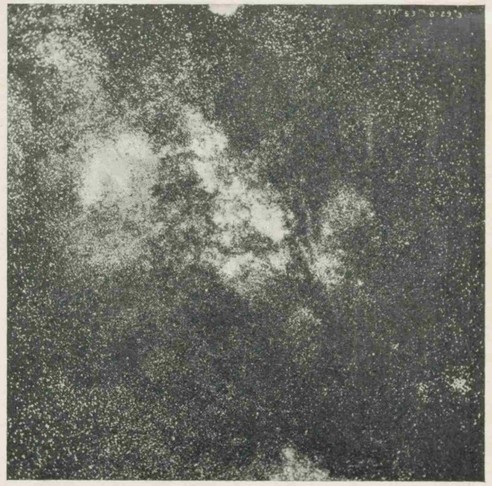

FIG. 3.
STAR CLOUDS IN SAGITTARIUS.
The Great Star Clouds in Sagittarius, from a 3 h. 58 m. exposure by Barnard.

Fig. 1 shows a portion of the heavens as they appear from about Lat. 50° N. looking south on an August evening. The zodiacal constellations Virgo, Libra, Scorpio, Sagittarius, Capricornus, and Aquarius lie low in the sky. The Milky Way comes down through the constellations Cygnus (Swan), Aquila (Eagle), Sagittarius (Archer), and portions of Ophinchus (Serpent-bearer) and Scorpio. Fig. 2 is from a four hour exposure by the late Professor E. E. Barnard of the upper western part of Sagittarius just below Aquila. It shows in striking manner the contrast between these bright portions of the Milky Way with their myriad stars and the darker regions to the westward where obscuring nebulosity—perhaps it is cool gaseous matter, perhaps it is meteoric dust—pervades interstellar space in this direction and almost completely cuts off our view of the stars behind it.

The great star clouds of Sagittarius are beautifully shown in Fig. 3, and the dark nebulosities of the adjacent constellation, Ophinchus, just to the westward, also present a remarkable appearance. Star counts indicate that as the dark nebulosity shown in the lower right of Fig. 3 is approached from every side, the number of stars is increased. The conclusion of Shapley is that if the obscuring curtain were not there the region of maximum star density, the nucleus or centre of our galaxy, would be revealed. Rich star clouds lie to the west, and a beautiful

FIG. 4.

THE GREAT NEBULA IN ANDROMEDA.

A spiral aggregation of a thousand million stars far out beyond the Milky Way, distant a million light years from the solar system. (From a Yerkes Observatory photograph.)

star cluster is situated near by. Behind this cluster and extending most densely to the north of it, is this vast, mysterious, enshrouding nebulosity completely hiding from our view the centre of the galaxy which is believed to be at a distance of some 47,000 light years in the direction of the background just above the cluster in this photograph.

Spectroscopic observations of the nearest spiral nebula, the Great Nebula in Andromeda (Fig. 4), has revealed the fact that it is in rotation about its centre, its period being of the order of seventeen million years. Is our great galaxy likewise in rotation? The distinguished Dutch astronomer, Oort, believes this to be the case, and he has calculated to what extent such rotation would affect the apparent motions of the stars as measured from the earth in different directions. Similar speculations have been made by two other astronomers, Lindblad and Schilt, while the first observational confirmation was announced by J. S. Plaskett of the Dominion Astrophysical Observatory in 1928. Quite recently Plaskett has produced more weighty evidence for the reality of this rotation, his study of the motions of some 800 very distant stars leading him to the conclusion that they are revolving about the central nucleus of the galaxy in a period of approximately one hundred million years.

Further confirmation of this vast galactic motion is afforded by a remarkable investigation recently concluded by O. Struve. He has studied the spectroscopic evidence for the presence of calcium atoms throughout the galaxy. Eddington had calculated a density of 10^{-24}, equivalent to about one atom per cubic centimetre, for this calcium substratum filling interstellar space. Struve's observational data points to a lesser density, 10^{-26} or one atom per 100 c.c. He has pointed out that this means that one per cent of all the matter in the galaxy is evenly spread out as a gaseous substratum, while ninety-nine per cent is condensed into stars and dense nebulae. But the relevant point in this connexion is that this widely disseminated calcium is found to partake in the galactic motion of rotation.

Have we now reached the climax in our survey of the motions of the heavenly bodies? We have noted the spin and wobble of our planet as it moves round and round the sun, which is itself speeding away towards the Hercules stars and simultaneously being carried around a vast orbit about the centre of this galaxy of ten thousand million stars. But what of our galaxy? Dayton Miller has made observations which may be interpreted as evidence for a galactic velocity of several thousand kilometres per second, but until confirmation is forthcoming it cannot be seriously considered. Undoubtedly, however, our galaxy is travelling through space as well as rotating about its centre. All the spiral nebulae have velocities relative to our system, and herein lies yet another mystery—why are these external far-off galaxies almost without exceptions speeding away from our galaxy with velocities of the order of several hundred miles per second? Are their velocities real or in part an illusory effect impressed upon the starlight as a result of its long journeying during many millions of years from one galaxy to another? Are these other galaxies and our own to be regarded as units in a super-aggregation having motions of its own, rotation, perhaps, and space velocity? Where is the centre of this super-system? If our giant galaxy be near it, then perhaps the recessional velocities of the other galaxies are to be explained as are the outward moving stars along each unwinding arm of every spiral galaxy —the super-system is perhaps a super-giant spiral!

These are questions to which to-day no answers can be given. The mystery of matter, the mystery of light, the mystery of motion! They baffle yet they challenge us, they over-awe, yet they inspire.

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